WHAT IS CLAIMED IS:

1. A method of generating a treatment table for ablating tissue using a scanning laser beam for generating scanning spots over a treatment region larger in area than the scanning spots, the method comprising:

providing a target function representing a desired lens profile for ablating the tissue by scanning spots of the laser beam on the tissue;

providing a basis function representing a treatment profile produced by scanning with overlapping scanning spots of the laser beam in a treatment pattern; and

fitting the target function with the basis function to obtain a treatment table including scanning spot locations and characteristics for the overlapping scanning spots of the laser beam.

2. The method of claim 1 wherein the basis function is a two-dimensional function representing a two-dimensional section of a three-dimensional treatment profile which has symmetry with respect to the two-dimensional section extending along the treatment pattern.

3. The method of claim 2 wherein the treatment pattern is generally linear or generally circular.

4. The method of claim 1 wherein the target function is a two-dimensional function representing a two-dimensional section of a three-dimensional lens profile which has symmetry with respect to the two-dimensional section extending along the treatment pattern.

5. The method of claim 4 wherein the target function represents an ablation depth as a function of a distance from an optical axis of a cornea.

6. The method of claim 1 wherein fitting the target function with the basis function includes fitting at N discrete evaluation points.

7. The method of claim 6 wherein the basis function includes M discrete basis functions representing M overlapping scanning spots.

8. The method of claim 7 wherein the M discrete basis functions represent M overlapping scanning spots across a treatment zone length representing the length across a generally two-dimensional section which is oriented normal across a

generally straight treatment pattern or which is oriented radially across a generally circular treatment pattern.

9. The method of claim 8 wherein the scanning spots are generally circular and have a generally uniform energy profile.

10. The method of claim 9 wherein

(A) for a treatment profile having a generally uniform two-dimensional section oriented normal across a generally straight treatment pattern, the discrete basis functions represent the two-dimensional section as

$$X_i(x_j) = y_i(x_j) = \sqrt{(s/2)^2 - (x_j - x_{0i})^2} \text{ or}$$

(B) for a treatment profile having a generally uniform two-dimensional section oriented radially across a generally circular treatment pattern, the discrete basis functions represent the two-dimensional section as

$$X_i(x_j) = \theta_i(x_j) = \cos^{-1}\left(\frac{x_j^{\,2} + x_{0i}^2 - (s/2)^2}{2 \cdot x_{0i} \cdot x_j}\right)$$

where

s is the diameter of the scanning spot;

$j = 1,\ldots,N$;

x_j is a reference x-coordinate for the two-dimensional section measured from an optical axis of the cornea of a j^{th} evaluation point for the center of the scanning spot;

x_{0i} is an x-coordinate for a center of an i^{th} scanning spot;

$(x_{0i} - s/2) \leq x_j \leq (x_{0i} + s/2)$;

$y_i(x_j)$ is a depth of the i^{th} basis function for the generally straight treatment pattern; and

$\theta_i(x_j)$ is a coverage angle of the i^{th} basis function for the generally circular treatment pattern.

11. The method of claim 10 wherein x_{0i} is specified for M number of equally spaced scanning spots as $x_{0i} = i * [\ (L - s + e) / M\ ]$,

where

L is the treatment zone length;

e is an extended zone; and

$i = 1,\ldots,M$.

12. The method of claim 11 wherein e is set to about 0.1 to about 0.5 mm.

13. The method of claim 7 wherein M is equal to about 7 to about 97.

14. The method of claim 7 further comprising refitting the target function with the basis function by varying the number of scanning spots M to iterate for a best fit.

15. The method of claim 6 wherein the target function is:

(A) for myopia and myopic cylinder,

$$f(x_j) = \sqrt{R_1^2 - x_j^2} - \sqrt{\left(\frac{R_1(n-1)}{n-1+R_1 D}\right) - x_j^2} + C \text{ or}$$

(B) for hyperopia and hyperopic cylinder,

$$f(x_j) = R_1 - \frac{R_1(n-1)}{n-1+R_1 D} - \sqrt{R_1^2 - x_j^2} + \sqrt{\left(\frac{R_1(n-1)}{n-1+R_1 D}\right) - x_j^2} \text{ or}$$

(C) for phototherapeutic keratectomy,

$f(x_j) = d$;

where

$0 \leq x_j \leq (L - shift)$;

$j = 0,1,\ldots,N-1$;

$$C = \sqrt{R_1^2 - s^2/4} + \sqrt{\left(\frac{R_1(n-1)}{n-1+R_1 D}\right) - s^2/4};$$

x_j is an x-coordinate measured from an optical axis of the cornea of the j^{th} evaluation point for the center of the scanning spot;

s is the diameter of the scanning spot;

R_1 is the anterior radius of curvature of the cornea in meters;

R_2 is the final anterior radius of curvature of the cornea in meters;

$n = 1.377$ is the index of refraction of the cornea;

D is the lens power of the scanning spot in diopters;

L is the treatment zone length representing the length across a generally uniform section which is oriented normal across a generally straight treatment pattern for myopic or hyperopic cylinders, or which is oriented radially across a generally circular treatment pattern for myopia or hyperopia;

shift is the amount of emphasis shift; and
d is a constant depth.

16. The method of claim 15 wherein the shift is about 0 to about 0.2.

17. The method of claim 15 wherein $x_j = j * [\,(L - shift) / N\,]$.

18. The method of claim 15 wherein the basis function includes *M* discrete basis functions representing *M* overlapping scanning spots, and wherein fitting the target function with the basis function comprises solving the following equation for coefficients a_i representing treatment depth for the ith scanning spot:

$$f(x_j) = \sum_{i=1}^{M} a_i X_i(x_j)$$

where

$X_i(x_j)$ is the ith basis function; and
i = 1,…,M.

19. The method of claim 6 wherein fitting the target function and the basis function comprises specifying a deviation for each of the *N* discrete evaluation points.

20. The method of claim 19 further comprising refitting the target function with the basis function by varying the deviations to iterate for a best fit.

21. The method of claim 1 wherein fitting the target function and the basis function comprises evaluating closeness of the fit and repeating the fitting step if the closeness does not fall within a target closeness.

22. The method of claim 1 wherein the target function and the basis function are fitted using a least square fit.

23. The method of claim 1 further comprising randomizing the scanning spot locations of the treatment table to produce a random scanning order.

24. The method of claim 1 further comprising refitting the target function with the basis function by varying the size of at least one of the scanning spots to iterate for a best fit.

25. The method of claim 1 wherein the scanning spot characteristics of a scanning spot at a scanning spot location include shape, size, and depth of the scanning spot at the scanning location.

26. The method of claim 1 wherein the scanning spots have different sizes.

27. The method of claim 1 further comprising specifying the treatment pattern for scanning with overlapping scanning spots of the laser beam.

28. The method of claim 1 wherein the target function and the basis function are fitted using a simulated annealing process.

29. The method of claim 1 further comprising specifying a merit function representing an error of fit between the target function and the basis function; and minimizing the merit function.

30. The method of claim 1 further comprising specifying a merit function representing an error of fit between the target function and the basis function; monitoring a total number of the scanning spots in the treatment table; and minimizing the merit function and the total number of the scanning spots in the treatment table.

31. The method of claim 1 further comprising refitting the target function with the basis function by selecting a scanning spot location and varying the characteristics of the scanning spot at the selected location to iterate for a best fit.

32. A method of generating a treatment table for ablating tissue using a scanning laser beam for generating scanning spots over a treatment region larger in area than the scanning spots, the method comprising:

providing a lens function representing a desired lens profile for ablating the tissue by scanning spots of the laser beam on the tissue;

providing a basis function representing a treatment profile produced by the overlapping scanning spots along a treatment path, the basis function representing a section oriented across the treatment path; and

fitting the lens function with the basis function to obtain a treatment table including scanning spot locations and characteristics for the overlapping scanning spots of the laser beam.

33. The method of claim 32 wherein the scanning spots are generally circular and have a generally uniform energy profile, and the basis function includes M discrete basis functions representing M overlapping scanning spots.

34. The method of claim 33 wherein the treatment profile is symmetrical with respect to an axis of symmetry, and the discrete basis functions are

$$\theta_i(x) = \cos^{-1}\left(\frac{x^2 + x_{0i}^2 - (s/2)^2}{2 \cdot x_{0i} \cdot x}\right)$$

where

s is the diameter of the scanning spot;

x is an x-coordinate measured from the axis of symmetry;

x_{0i} is an x-coordinate for a center of an i^{th} scanning spot;

$(x_{0i} - s/2) \leq x \leq (x_{0i} + s/2)$; and

$\theta_i(x)$ is a coverage angle of the i^{th} basis function.

35. The method of claim 34 wherein x_{0i} is specified for M number of equally spaced scanning spots as:

$$x_{0i} = i * [\ (L - s + e) / M\ ],$$

where

L is the treatment zone length of the section oriented radially across the treatment profile;

e is an extended zone; and

$i = 1,\ldots,M$.

36. The method of claim 34 wherein fitting the lens function with the basis function comprises solving the following equation for coefficients a_i representing treatment depth for the i^{th} scanning spot:

$$f(x) = \sum_{i=1}^{M} a_i X_i(x)$$

where

$f(x)$ is the lens function; and

i = 1,…,M.

37. The method of claim 36 wherein the lens function is:

(A) for myopia,

$$f(x) = \sqrt{R_1^2 - x^2} - \sqrt{\left(\frac{R_1(n-1)}{n-1+R_1 D}\right) - x^2} + C \text{ or}$$

(B) for hyperopia,

$$f(x) = R_1 - \frac{R_1(n-1)}{n-1+R_1 D} - \sqrt{R_1^2 - x^2} + \sqrt{\left(\frac{R_1(n-1)}{n-1+R_1 D}\right) - x^2} \text{ or}$$

(C) for phototherapeutic keratectomy,

$f(x) = d$;

where

$$0 \leq x \leq (L - shift);$$

$$C = \sqrt{R_1^2 - s^2/4} + \sqrt{\left(\frac{R_1(n-1)}{n-1+R_1 D}\right) - {s^2}/{4}};$$

s is the diameter of the scanning spot;

R_1 is the anterior radius of curvature of the cornea in meters;

R_2 is the final anterior radius of curvature of the cornea in meters;

$n = 1.377$ is the index of refraction of the cornea;

D is the lens power of the scanning spot in diopters;

L is the treatment zone length;

shift is the amount of emphasis shift; and

d is a constant depth.

38. The method of claim 36 further comprising dividing the depth (a_i) for the ith scanning spot by a depth per pulse of the laser beam to obtain a number of pulses per an ith treatment ring for the ith scanning spot; and dividing the number of pulses per treatment ring by 2π to obtain an angular spacing between pulses for the ith treatment ring.

39. The method of claim 32 wherein the scanning spots have a fixed spot size and a fixed spot shape.

40. The method of claim 32 wherein at least one of the spot size and spot shape of the scanning spot is variable.

41. A method for fitting a three-dimensional target profile, the method comprising:

providing a two-dimensional basis function including overlapping portions to represent a three-dimensional profile which has symmetry with respect to a two-dimensional section extending along a treatment pattern; and

fitting the three-dimensional target profile with the two-dimensional basis function to obtain a distribution of the overlapping portions.

42. The method of claim 41 wherein the three-dimensional profile has symmetry with respect to a two-dimensional section oriented radially from an axis of symmetry and extending in a generally circular treatment pattern around the axis.

43. The method of claim 42 wherein the overlapping portions are generally circular, and the two-dimensional basis function comprises discrete basis functions each representing a coverage angle of one of the overlapping portions as a function of a distance from the axis of symmetry.

44. The method of claim 41 wherein the three-dimensional profile has symmetry with respect to a two-dimensional section oriented normal across a generally straight treatment pattern.

45. The method of claim 44 wherein the overlapping portions are generally circular, and the two-dimensional basis function comprises discrete basis functions each representing a depth of one of the overlapping portions as a function of a distance from the axis of symmetry.

46. A system for ablating tissue, the system comprising:

a laser for generating a laser beam;

a delivery device for delivering the laser beam to a tissue;

a controller configured to control the laser and the delivery device; and

a memory, coupled to the controller, comprising a computer-readable medium having a computer-readable program embodied therein for directing operation of

the system, the computer-readable program including a first set of instructions for generating a treatment table including scanning spot locations and characteristics for ablating the tissue over a treatment region larger in area than the spot size of the laser beam to achieve a desired lens profile for ablating the tissue, a second set of instructions for controlling the laser to generate the laser beam, and a third set of instructions for controlling the delivery device to deliver the laser beam to the tissue according to the treatment table.

47. The system of claim 46 wherein the first set of instructions of the computer-readable program includes:

a first subset of instructions for providing a target function representing the desired lens profile for ablating the tissue by scanning spots of the laser beam on the tissue;

a second subset of instructions for providing a basis function representing a treatment profile produced by the overlapping scanning spots in a treatment pattern; and

a third subset of instructions for fitting the target function with the basis function to obtain the treatment table including the scanning spot locations and characteristics for the overlapping scanning spots of the laser beam.

48. The system of claim 47 wherein the second subset of instructions provide a basis function which is a two-dimensional function representing a two-dimensional section of a three-dimensional treatment profile having symmetry with respect to the two-dimensional section extending along the treatment pattern.

49. The system of claim 47 wherein the first set of instructions of the computer-readable program includes a fourth subset of instructions for refitting the target function with the basis function by varying the spot size of the laser beam to iterate for a best fit.

50. The system of claim 47 wherein the first set of instructions of the computer-readable program includes a fifth subset of instructions for evaluating closeness of the fit and repeating the fitting step if the closeness does not fall within a target closeness.

51. The system of claim 47 wherein the first set of instructions of the computer-readable program includes a sixth subset of instructions for randomizing the scanning spot locations for the treatment table to produce a random scanning order.

52. The system of claim 47 wherein the first set of instructions of the computer-readable program includes a seventh subset of specifying the treatment pattern for scanning with overlapping scanning spots of the laser beam;

53. The system of claim 47 wherein the scanning spot characteristics of a scanning spot at a scanning location include shape, size, and depth of the scanning spot at the scanning location.

54. The system of claim 47 wherein the desired lens profile is selected from the group consisting of an elliptical profile, a hyperopic elliptical profile, a myopic elliptical profile, a circular profile, and a linear profile.

55. The system of claim 47 wherein the desired lens profile is asymmetric.

56. The system of claim 47 wherein the desired lens profile comprises an arbitrary two-dimensional lens profile.